November 15, 2021

Dear AO/PV blog readers:

We have shifted the public release of the Arctic Oscillation/Polar Vortex blog to Wednesdays weekly through the winter season.

For those who would like an early look on Mondays, we will be offering at a nominal price (US $25) a PDF version of the upcoming blog, and we will be rolling out in the coming weeks access to the datasets used in the production of this blog. At present we plan to make available in comma-separated values the timeseries of the Polar Cap Height and the timeseries of the Wave Activity Flux (vertical component), though we would appreciate to hear your suggestions for additional data of interest to you all.

Special blog on winter 2018/2019 retrospective can be found here - http://www.aer.com/winter2019

Special blog on winter 2017/2018 retrospective can be found here - http://www.aer.com/winter2018

Special blog on winter 2016/2017 retrospective can be found here - http://www.aer.com/winter2017

Special blog on winter 2015/2016 retrospective can be found here - http://www.aer.com/winter2016

Dr. Judah Cohen from Atmospheric and Environmental Research (AER) embarked on an experimental process of regular research, review, and analysis of the Arctic Oscillation (AO) and Polar Vortex (PV). This analysis is intended to provide researchers and practitioners real-time insights on one of North America's and Europe's leading drivers for extreme and persistent temperature patterns.

During the winter schedule the blog is updated once every week. Snow accumulation forecasts replace precipitation forecasts. Also, there is renewed emphasis on ice and snow boundary conditions and their influence on hemispheric weather. With the start of spring we transition to a spring/summer schedule, which is once every two weeks. Snow accumulation forecasts will be replaced by precipitation forecasts. Also, there will be less emphasis on ice and snow boundary conditions and their influence on hemispheric weather.

Subscribe to our email list or follow me on Twitter (@judah47) for notification of updates.

The AO/PV blog is partially supported by NSF grant AGS: 1657748.

Summary

- The Arctic Oscillation (AO) is currently slightly positive and is predicted to slowly trend negative this week and then straddle neutral to negative next week through the end of the month with mixed pressure/geopotential height anomalies across the Arctic and mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic

Oscillation (NAO) is currently positive and is predicted to also trend negative as pressure/geopotential height anomalies are currently negative across Greenland but are predicted to turn positive across Greenland next week.

- This week troughing/negative geopotential height anomalies across Greenland will favor ridging/positive geopotential height anomalies coupled with normal to above temperatures across much of Europe including the United Kingdom (UK). However next week strengthening ridging/positive geopotential height anomalies centered just south of Greenland will promote deepening troughing/negative geopotential height anomalies and northerly flow coupled with normal to below normal temperatures across Northern and Western Europe including the UK with milder temperatures across Southeastern Europe.
- The predicted general pattern across Asia the next two weeks is troughing/negative geopotential height anomalies coupled with normal to below temperatures in Western and East Asia with ridging/positive geopotential height anomalies coupled with normal to above normal temperatures across much of Siberia.
- The pattern across North America this week is troughing/negative geopotential height anomalies coupled with normal to below normal temperatures in Alaska and much of Canada with ridging/positive geopotential height anomalies coupled with normal to above temperatures draped across the United States (US). However, next week strengthening ridging/positive geopotential height anomalies coupled with normal to above temperatures across the Western US and just south of Greenland will contribute to deepening troughing/negative geopotential height anomalies coupled with normal to below temperatures in Southeastern Canada and the Eastern US.
- In the *Impacts* section I discuss what I see as mixed signals and uncertainty for the winter forecast.

Plain Language Summary

I see many mixed signals for the upcoming winter. In the Impacts section I list the signs that I see that favor either an overall warm or cold winter. Lack of high pressure near the Urals, a strong polar vortex, North Pacific sea surface temperatures favor a warm winter. Bouts of cold and snow this month in Asia, the pattern of Arctic sea ice extent anomalies and high pressure in the northern North Atlantic favor a cold winter.

Impacts

This is the annual time of year when panic sets in about the winter forecast. And it is not so much that the forecast that I posted last week is correct, but it is more about correctly anticipating the influence of important features on the general atmospheric circulation during the winter months. I do find that there are several maybe even many mixed signals just two weeks away from the official start of winter. I thought it might be helpful for the reader what are the main signals that I am watching (though admittedly I can be wrong about what I am focusing my attention on missing the critical factors) and maybe it will also serve as therapy for my anxiety.

Signals favoring an overall warm winter:

Lack of Ural blocking. As I have tried to make clear last week, I have come to a great appreciation for the role Ural high pressure/blocking or the absence of can play on the large-scale atmospheric circulation. Rightly or wrongly, I do feel that it is very difficult or even impossible to have widespread cold temperatures without a disrupted polar vortex, and those disruptions don't necessarily need to be very large. And inversely a strong and quiet polar vortex is close to a guarantee of widespread, relatively mild temperatures across the Northern Hemisphere. And in my opinion the atmospheric feature most critical for disrupting the polar vortex is Ural blocking. Also, the Ural blocking needs to persist longer than synoptic time scales so on the order of weeks and not days to have its biggest impact. As you can see in **Figures 2, 5** and **8** there are no signs yet of Ural blocking for the remainder of the month but instead Ural troughing and consequently the polar vortex is predicted to remain relatively strong for the foreseeable future. But so far, the Ural blocking is not an extension of a mid-tropospheric low centered near the North Pole. With the low center meandering across northern Eurasia, does allow the possibility of cold weather across the continents much more so than if there was one deep low center over the North Pole.

The relatively strong polar vortex. A strong polar vortex can be associated with a mild and prolonged mild period at that if it couples to the surface. I see no signs that the strong polar vortex in the mid-stratosphere has coupled to the surface or that it will in the next two weeks. But as long as the PV remains strong the risk exists and is even elevated for a mild and persistent pattern. I believe that Ural troughing and a strong PV became phase locked and mutually reinforcing and that is the main reason for the very mild winter from end-to-end in 2019/20.

The negative Pacific Decadal Oscillation (PDO). The consensus is (and I see little reason to argue) that the negative phase of the PDO favors a trough further west across North America with more ridging in the Eastern US and therefore milder temperatures. The same could be argued for La Niña but I would be more inclined to hedge a warm East Coast with a strong La Niña. There have been some blockbuster Eastern US winters with weak to moderate La Niñas. The one feature related to the negative PDO that concerns me most is the disappearance of the "warm blob" in the Gulf of Alaska or maybe more accurately it's migration to the central North Pacific. I do think that it probably contributed to ridging just offshore or long the west coast of North America that sustained troughing in eastern North America for most of the past decade. But this idea that extratropical sea surface temperatures can force the phase and amplitude of mid-tropospheric waves is far from settled.

Signals favoring an overall cold winter:

Cold and snow in Asia. Snow cover across the Northern Hemisphere and cold temperatures have in general been lackluster and lacking. The biggest exception I feel is in Asia. Snow cover had a big burst in early November across Asia. It has stalled a bit but looks to pick up again. Also, the cold in Asia is not impressive by any stretch but it has come in spurts. I do think that the cold and snow associated with troughs in Central and East Asia has been enough to keep the polar vortex off balance so as not to become a runaway train. There haven't been any large disruptions of the PV but some minor ones including what I believe to be an ongoing stretched PV event. And though the PV is quite circular in the mid-stratosphere for the end of the month (see

Figure 13) it is predicted to appear a lot more disrupted in the lower stratosphere with deep troughing and northerly flow over eastern North America (see **Figure i**). In fact I think that there are signs there is enough troughing in East Asia to kick off enough wave energy to at least maintain the disrupted configuration of the lower-stratospheric PV. The lack of coupling between the mid and lower stratosphere has not precluded the possibility of cold patterns across the Northern Hemisphere.

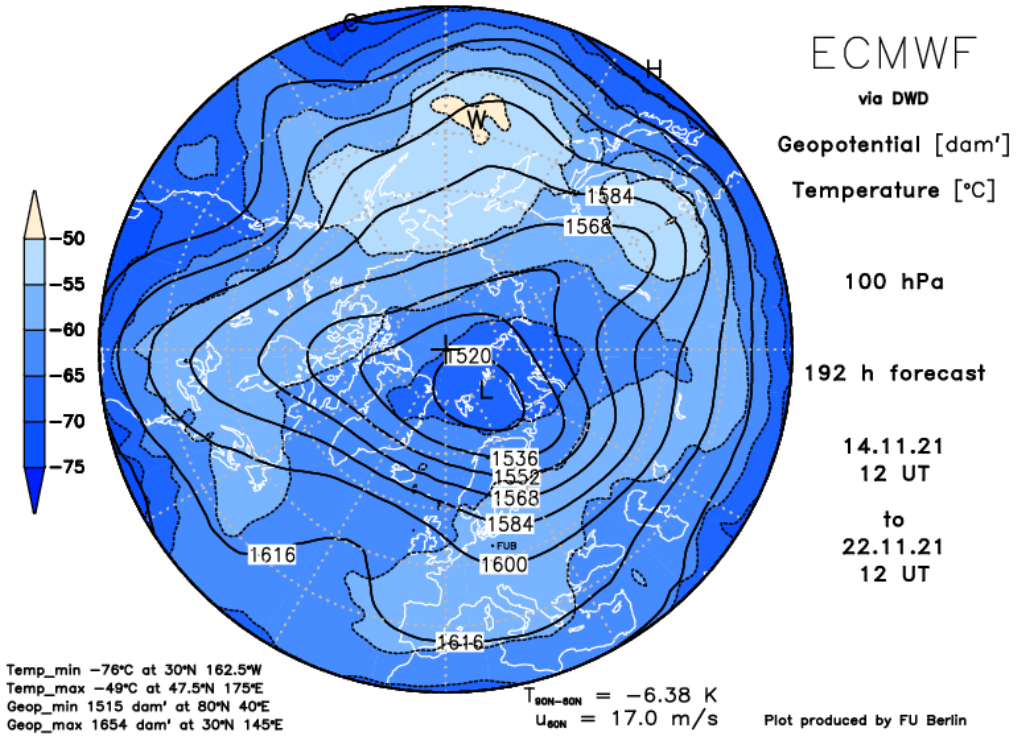

Figure i. Forecasted 100 hPa geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 22 November 2021 from the 12Z 14 November 2021 ECMWF forecast.

North Atlantic blocking. The EPS was the first to show this but has now been followed by the GFS, blocking/high pressure in the North Atlantic looks to be the dominant atmospheric feature to end the month of November. Though it is not centered over Greenland, it is looking to be in better and better position to facilitate, troughing, cold and snow in both Europe and the Eastern US. I don't foresee this feature as lasting long enough to influence the weather averages but could make for an interesting start to winter and could be a precursor to Ural blocking and/or a stretched polar vortex event.

Arctic sea ice. Negative Arctic sea ice extent anomalies are focused on the North Atlantic side of the Arctic (Barents-Kara Seas and Baffin Bay) and may actually be slightly above normal on the North Pacific side of the Arctic (Chukchi and Bering Seas) as seen in **Figure 16**. Based on recent research this may be the most optimal pattern of sea ice anomalies for disrupting the

PV. Low sea ice on the North Atlantic side of the Arctic is also related to Greenland and Ural blocking, which is favorable for cold weather in Europe and Asia respectively and to a lesser extent the Eastern US. But of course, the surface needs to couple with the atmosphere and so far, I haven't seen much evidence of this.

I think I have covered many other features that other long-range forecasters are following with one possible exception the quasi-biennial oscillation (QBO). Of late it hasn't been living up its name, but I find it too complex to pay too much attention to. It seems that most followers of the QBO cycle consider it to be in the easterly phase that favors a more disrupted PV and colder temperatures across the Northern Hemisphere continents. So I will trepidatiously put it in the cold column.

1-5 day

The AO is predicted to be mostly positive this week **(Figure 1**) as geopotential height anomalies are predicted to be mostly negative across the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with mostly negative geopotential height anomalies predicted across Greenland (**Figure 2**), the NAO is predicted to be positive as well (**Figure 1**).

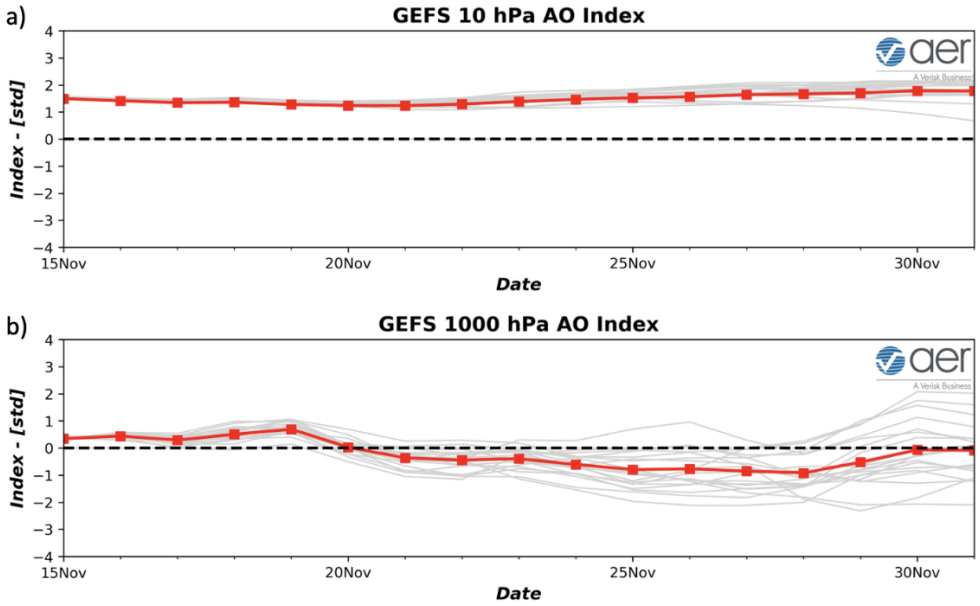

Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 8 November 2021 GFS ensemble. (b)The predicted daily-mean near-surface AO from the 00Z 15 November 2021 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, troughing/negative geopotential height anomalies across Greenland will partially force ridging/positive geopotential height anomalies across much of Europe including the UK with troughing/negative geopotential height anomalies limited to Northern Europe this period

(**Figures 2).** This will result in normal to above normal temperatures across most of Europe including the UK (**Figure 3**). The ridging/positive geopotential height anomalies centered over Europe will contribute to deepening troughing/negative geopotential height anomalies in Western and Central Asia with ridging/positive geopotential height anomalies Eastern Asia especially Eastern Siberia (**Figure 2**). This pattern favors normal to below normal temperatures in Western and Central Asia with normal to above normal temperatures in Eastern Asia **(Figure 3**).

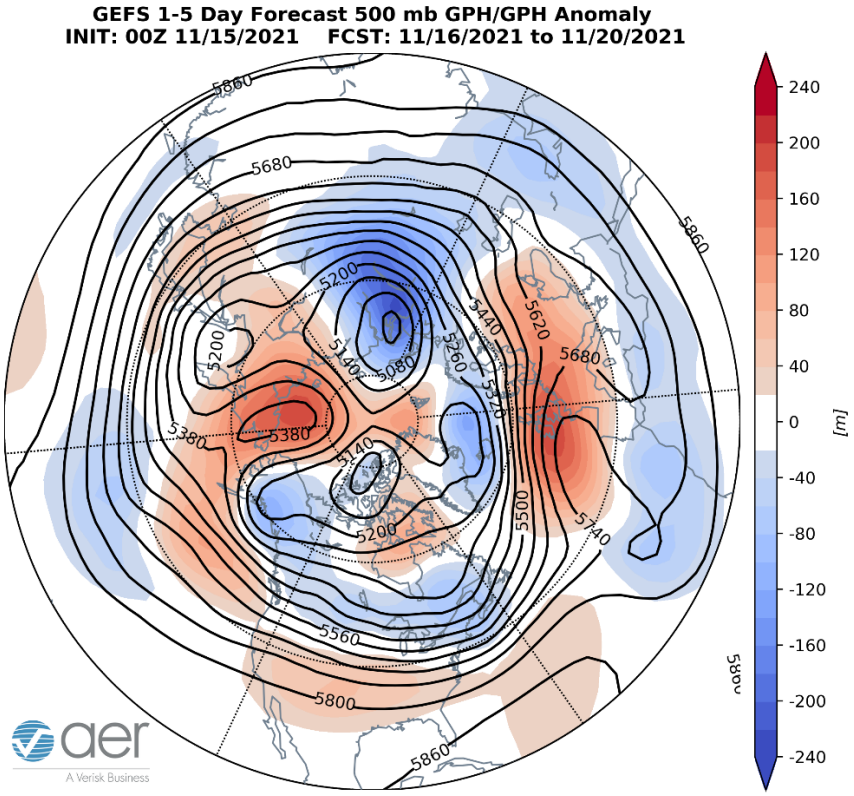

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 16 – 20 November 2021. The forecasts are from the 00z 15 November 2021 GFS ensemble.

The general pattern this week across North America is mostly zonal with troughing/negative geopotential height anomalies across Alaska and much of Canada with ridging/positive geopotential height anomalies to the south across the US **(Figure 2).** This pattern is predicted to bring normal to below normal temperatures across Alaska. Western Canada and the US Pacific Northwest with normal to above normal temperatures across much of Eastern Canada and the US **(Figure 3).**

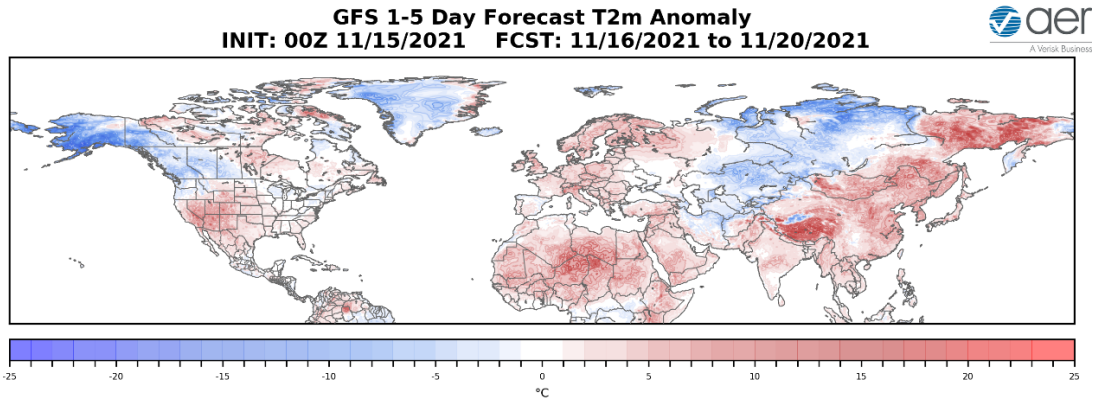

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 16 – 20 November 2021. The forecast is from the 00Z 15 November 2021 GFS ensemble.

Troughing and/or cold temperatures are predicted to support new snowfall across Norway and much of Northern Asia while mild temperatures promote snowmelt in Northwestern Asia and Northeastern China (**Figure 4**). Troughing and/or cold temperatures are predicted to support new snowfall across Eastern Alaska and Western and Central Canada while mild temperatures promote snowmelt in the US Upper Midwest and the northern Appalachians (**Figure 4**).

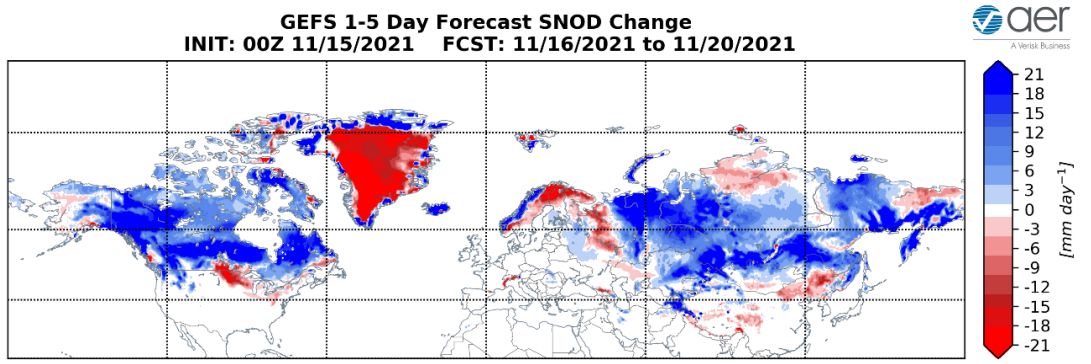

Figure 4. Forecasted snow depth changes (mm/day; shading) from 16 – 20 November 2021. The forecast is from the 00Z 15 November 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to turn mostly negative this period **(Figure 1**) as geopotential height anomalies remain mixed across the Arctic but turn positive across Greenland with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with weak positive geopotential height anomalies continuing across Greenland (**Figure 5**), the NAO is predicted to be negative this period.

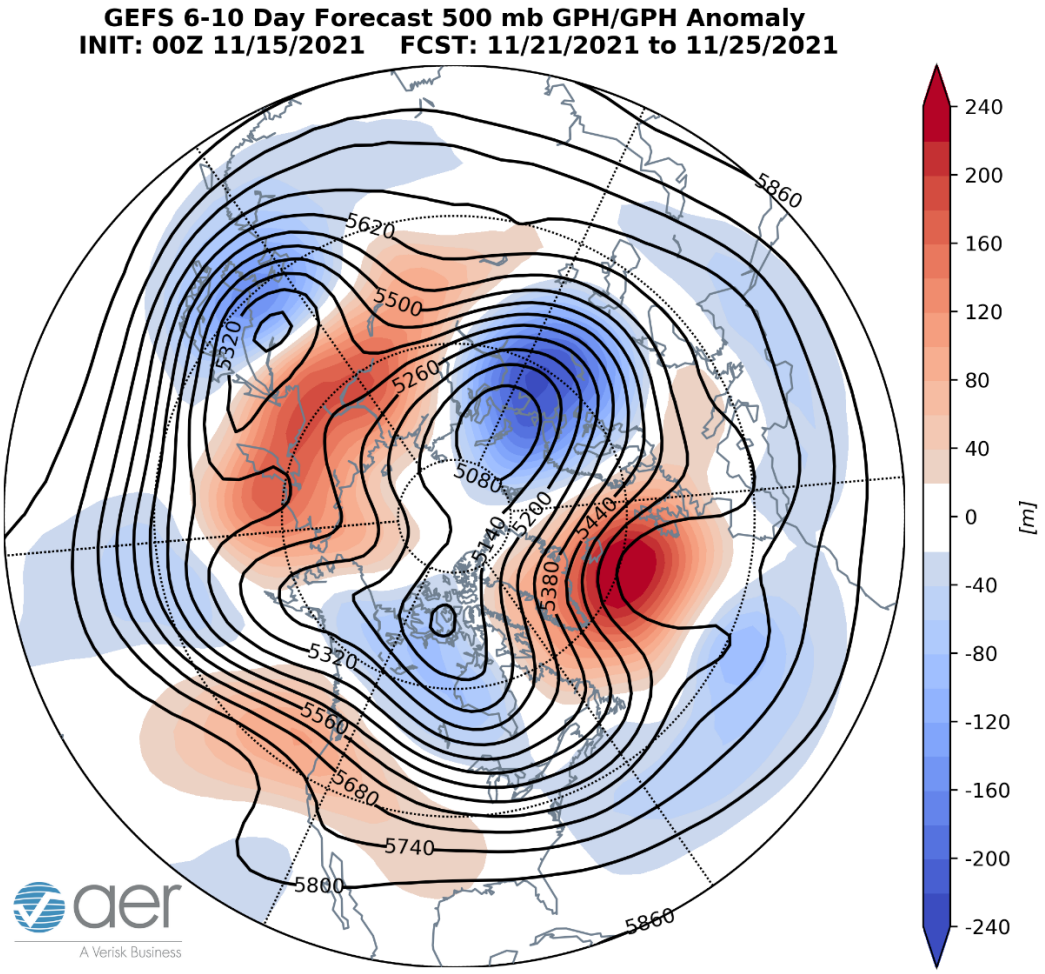

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 21 – 25 November 2021. The forecasts are from the 00z 15 November 2021 GFS ensemble.

Developing ridging/positive troughing/negative geopotential height anomalies south of Greenland and Iceland will contribute to troughing/negative geopotential height anomalies and northerly flow across Western Europe with southwesterly flow across Eastern Europe this period (**Figures 5).** This will result in normal to below normal temperatures across much of Western and Northern Europe including the UK with normal to above normal temperatures across Eastern Europe (**Figure 6**). Strengthening ridging/positive geopotential height anomalies centered over Eastern Siberia and the south of Greenland will contribute to both deepening troughing/negative geopotential height anomalies in Western and East Asia with ridging/positive geopotential height anomalies in Central Asia this period (**Figure 5**). This pattern favors normal to below normal temperatures across Western and East Asia with normal to above normal temperatures in Central Asia and much of Siberia **(Figure 6**).

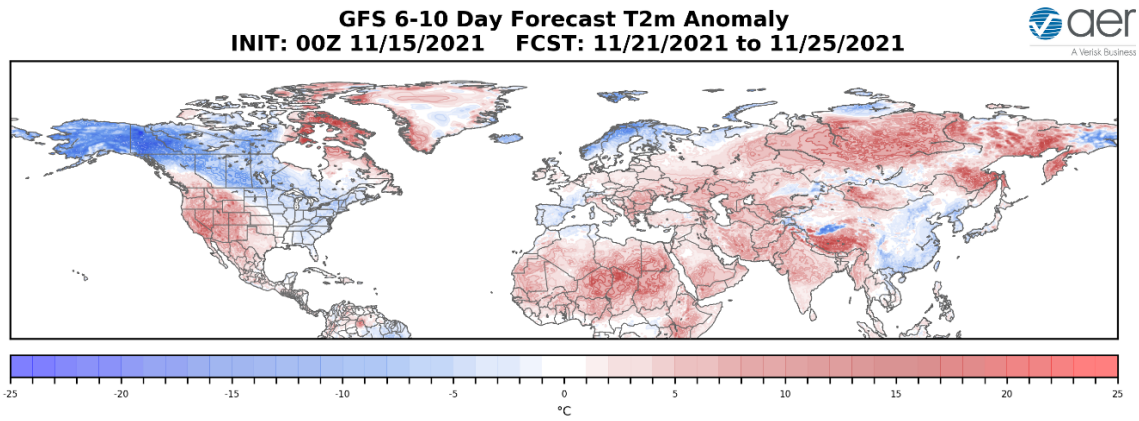

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 21 – 25 November 2021. The forecasts are from the 00Z 15 November 2021 GFS ensemble.

Strengthening ridging/positive geopotential height anomalies across the Western US will contribute to deepening troughing/negative geopotential height anomalies previously in the Eastern US this period **(Figure 5).** This will pull southeastward normal to below normal temperatures across Alaska and Western Canada into Central Canada and the Eastern US with normal to above normal temperatures in the Western US and Northeastern Canada **(Figure 6).**

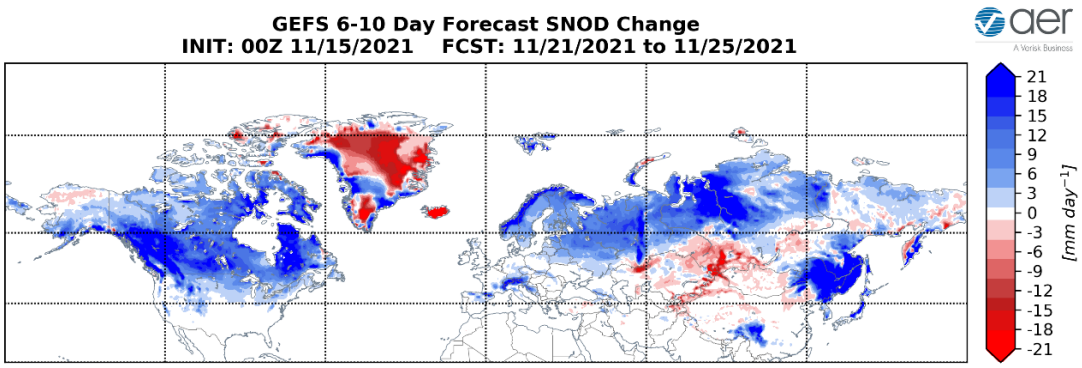

Figure 7. Forecasted snow depth changes (mm/day; shading) from 21 – 25 November 2021. The forecast is from the 00Z 15 November 2021 GFS ensemble.

Troughing and/or cold temperatures are predicted to support new snowfall across Scandinavia, the Alps, Northeastern Europe, Northern Asia and especially Northeastern Asia while milder temperatures promote snowmelt across Central Asia (**Figure 7**). Troughing and/or cold temperatures are predicted to support new snowfall across southern Alaska, much of Canada, the Northern US and the US Rockies (**Figure 7**).

11-15 day

With mixed geopotential height anomalies predicted across the Arctic but positive across Greenland and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure**

8), the AO should remain neutral to negative this period (**Figure 1**). With predicted positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is forecasted to remain negative this period as well.

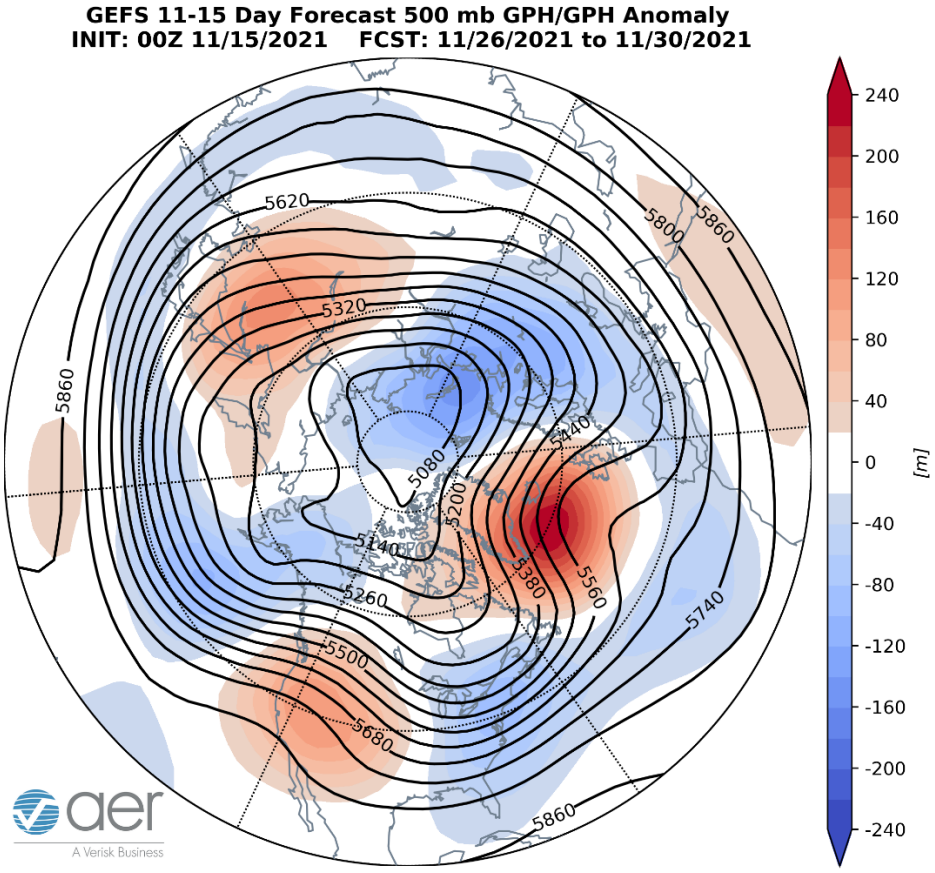

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 26 – 30 November 2021. The forecasts are from the 00z 15 November 2021 GFS ensemble.

Persistent ridging/positive geopotential height anomalies centered south of Greenland and Iceland will help anchor troughing/negative geopotential height anomalies and northerly flow across Northern and Western Europe this period (**Figure 8**). This pattern favors widespread normal to below normal temperatures across much of Western and Northern Europe including the UK with normal to above normal temperatures confined to Southeastern Europe under southwesterly flow this period (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to be focused in Northeastern Asia with persistent troughing/negative geopotential height anomalies in West and Southeast Asia this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across much of Asia except for normal to below normal temperatures across Northwestern and Southeastern corners of Asia this period (**Figure 9**).

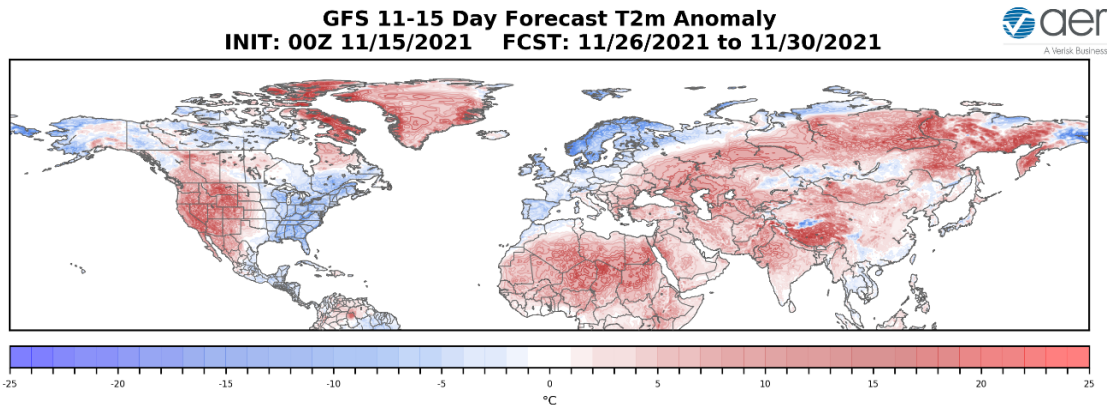

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 26 – 30 November 2021. The forecasts are from the 00z 15 November 2021 GFS ensemble.

Persistent ridging/positive geopotential height anomalies in the Western US will continue to favor downstream troughing/negative geopotential height anomalies across the Central and Eastern US with persistent troughing/negative geopotential height anomalies in Alaska this period (**Figure 8**). This pattern favors normal to below normal temperatures widespread across Alaska, Southeastern Canada and the Eastern US with normal to above normal temperatures in Northeastern Canada and the Western US (**Figure 9**).

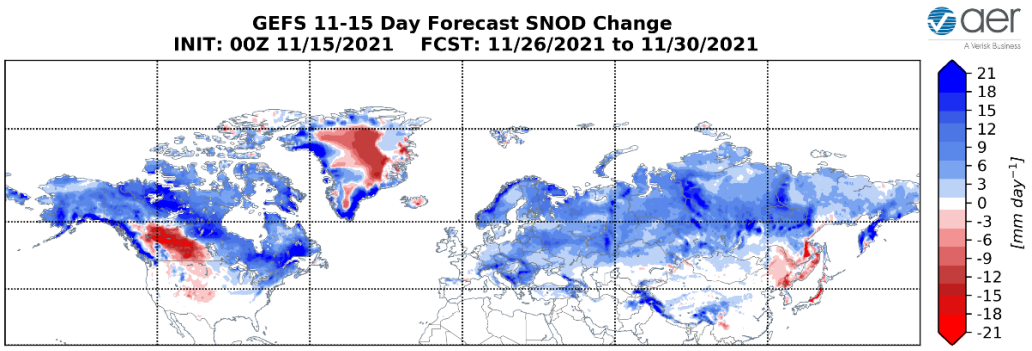

Figure 10. Forecasted snow depth changes (mm/day; shading) from 26 – 30 November 2021. The forecast is from the 00Z 15 November 2021 GFS ensemble.

Troughing and/or cold temperatures are predicted to support possible new snowfall across Scandinavia, Central and Eastern Europe, the Alps and Northern Asia while milder temperatures promote snowmelt across Northeast Asia (**Figure 10**). Troughing and/or cold temperatures are predicted to support possible new snowfall across Alaska, much of Northern and Eastern Canada and the Northeastern US while milder temperatures promote snowmelt across Southwestern Canada (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to cold/negative PCHs in the stratosphere and near normal PCHs in the troposphere (**Figure 11**). However, PCHs in the troposphere and especially the lower troposphere are predicted to transition warm/positive while cold/negative PCHs in the stratosphere are predicted to deepen next week (**Figure 11**). So unusual variability in the PCHs are predicted over the next two weeks with still little sign of stratosphere-troposphere coupling (though PCHs don't necessarily show coupling related to polar vortex stretching).

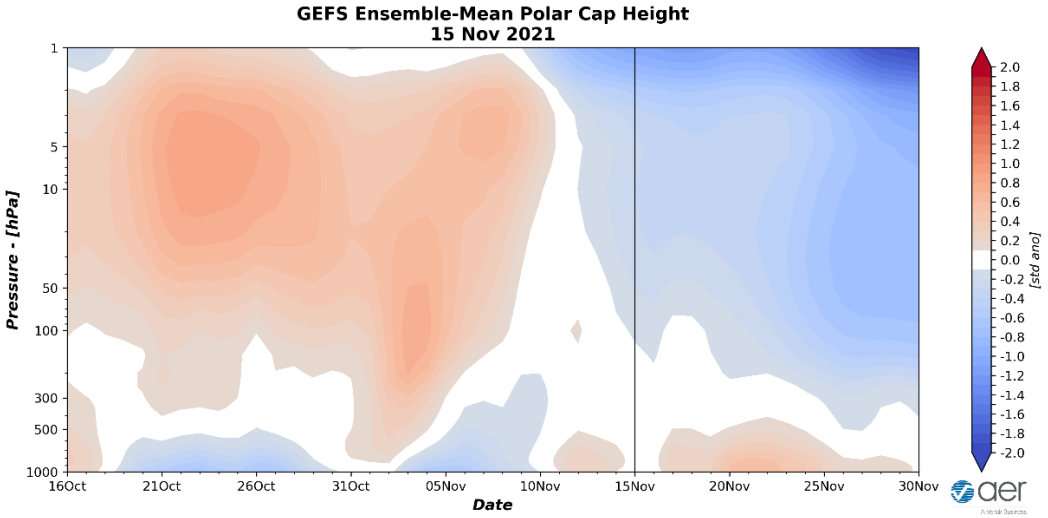

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 15 November 2021 GFS ensemble.

The current near normal PCHs in the lower tropospheric PCHs are consistent with the predicted weak surface AO this week (**Figure 1**). However, as PCHs transition to warm/positive in the lower troposphere next week, the surface AO will also likely be negative next week (**Figure 1**).

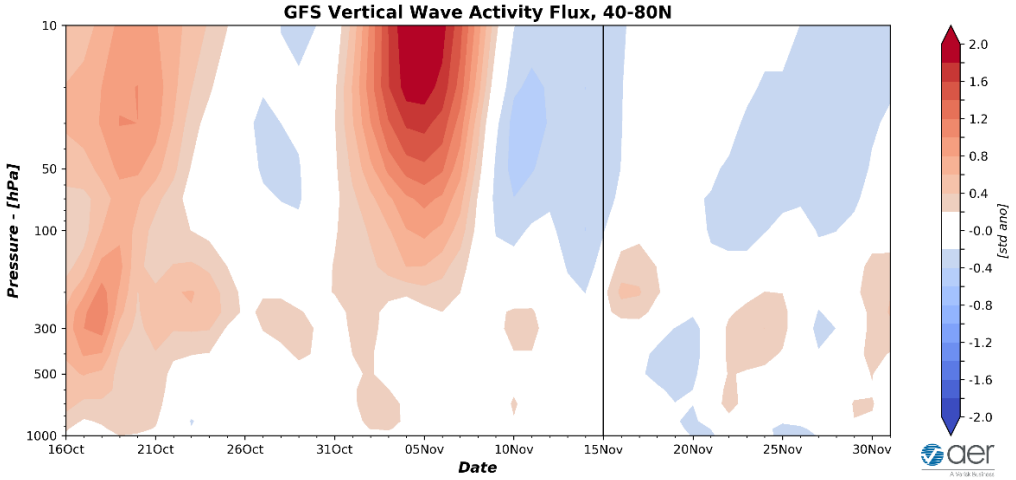

Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 15 November 2021 GFS ensemble.

The vertical Wave Activity Flux (WAFz) from the troposphere to the stratosphere or poleward heat transport in the stratosphere that has been below normal last week (**Figure 12**). Mostly normal to below normal WAFz is predicted for the remainder of the month (**Figure 12**). Relatively weak WAFz anomalies allows the polar vortex to strengthen.

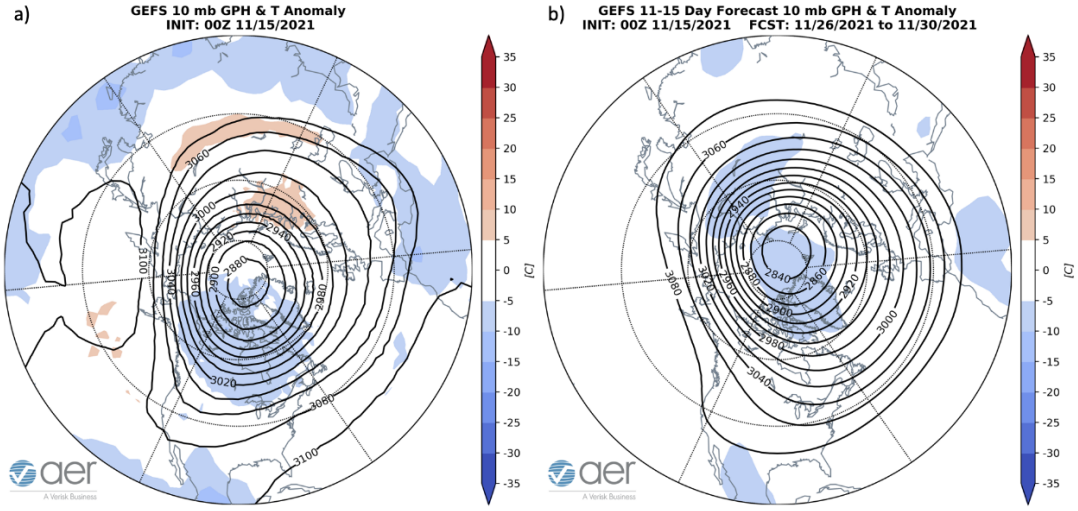

Figure 13. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 15 November 2021. (b) Same as (a) except forecasted averaged from 26 – 30 November 2021. The forecasts are from the 00Z 15 November 2021 GFS model ensemble.

The WAFz earlier this month did slightly perturbed the stratospheric PV, with the PV currently centered near the North Pole (**Figure 13**). The only slightly perturbed PV is resulting in a positive stratospheric AO (**Figure 11**). The relatively quiet WAFz will contribute to a relatively strong PV centered near the North Pole over the next two weeks (**Figure 13**) coupled with a persistent positive stratospheric AO this week into next week (**Figure 11**).

It does appear to me that the weak ridging in the polar stratosphere centered near the Dateline with below normal geopotential heights over Canada (**Figure 13**) is suggestive of an ongoing stretched polar vortex event. A stretched polar vortex is associated with cold temperatures first in Central and East Asia and then across Canada and the US east of the Rockies. We have already observed some cold air into Central and East Asia. It is looking more likely that this will be followed by a period of below normal temperatures and an expansion of snow cover across central and eastern North America including the Eastern US.

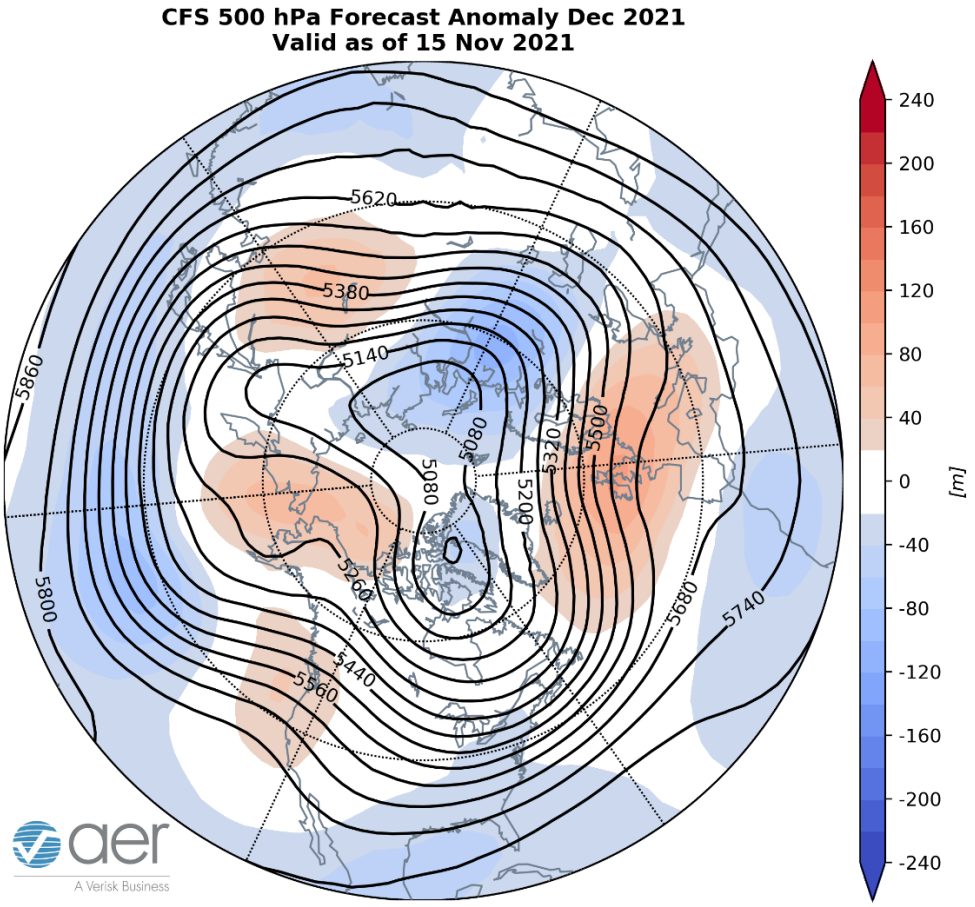

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for December 2021. The forecasts are from the 00Z 15 November 2021 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and surface temperatures for December (**Figure 15**) from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging centered over the UK, East Asia, the Dateline and the west coast of North America with troughing in Western Asia and eastern North America (**Figure 14).** This pattern favors seasonable to relatively warm temperatures widespread across Europe, Northwestern and Southeastern Asia, especially Siberia and Western Canada with seasonable to relatively cold across Northern Scandinavia, Northwestern Asia, Southeastern Canada and the Eastern US (**Figure 15).** I am very skeptical of this forecast and just looks like a persistence forecast from the CFS.

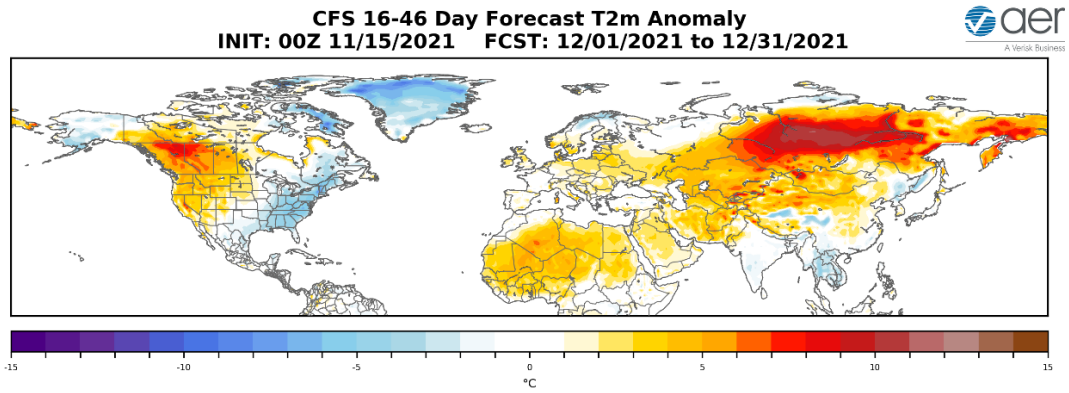

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for December 2021. The forecasts are from the 00Z 15 November 2021 CFS.

Surface Boundary Conditions

Arctic Sea ice

Arctic sea ice is growing but remains well below normal east of Greenland but especially in Baffin Bay and in the Barents-Kara Seas. Sea ice is close to normal in the Canadian Archipelagos and in the Chukchi Sea. Below normal sea ice in the Barents-Kara seas favors cold temperatures in Central and East Asia, while below normal sea ice in Baffin Bay favors cold temperatures in the Eastern Europe and Northern Europe however this topic remains controversial. Recent research has shown that the regional anomalies that are most highly correlated with the strength of the stratospheric PV are across the Barents-Kara seas region where low Arctic sea ice favors a weaker winter PV. Low sea ice in the Chukchi, Beaufort and Bering seas may favor colder temperatures across North America but has not been shown to weaken the PV.

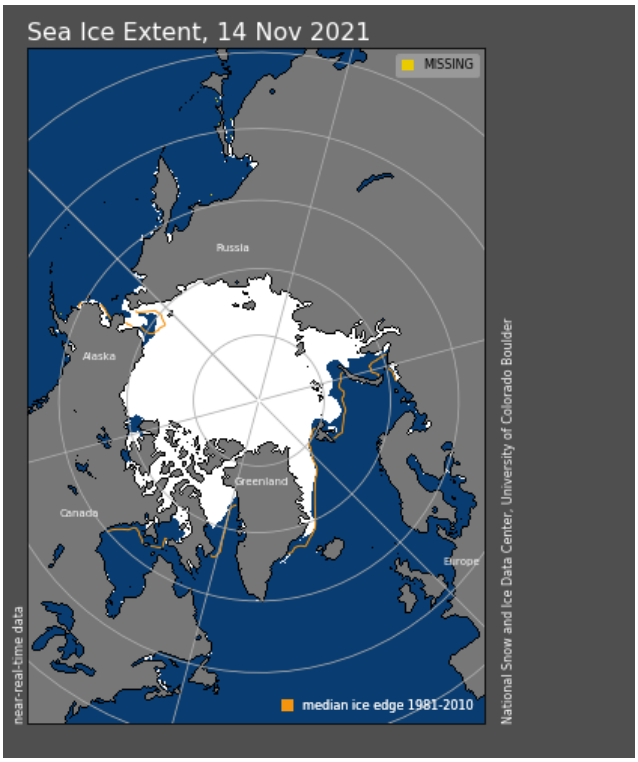

Figure 16. Observed Arctic sea ice extent on 14 November 2021 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are below normal, and we continue to observe weak La Niña conditions (**Figure 17**) and La Niña conditions are expected through the winter. Observed SSTs across the NH remain well above normal especially in the central North Pacific (west of recent years), the western North Pacific and offshore of eastern North America though below normal SSTs exist regionally especially in the North Pacific. Not my expertise but the SST pattern in the North Pacific are strongly resembling a negative Pacific Decadal Oscillation (PDO) pattern that favors colder temperatures across northwestern North America and milder temperatures across southeastern North America.

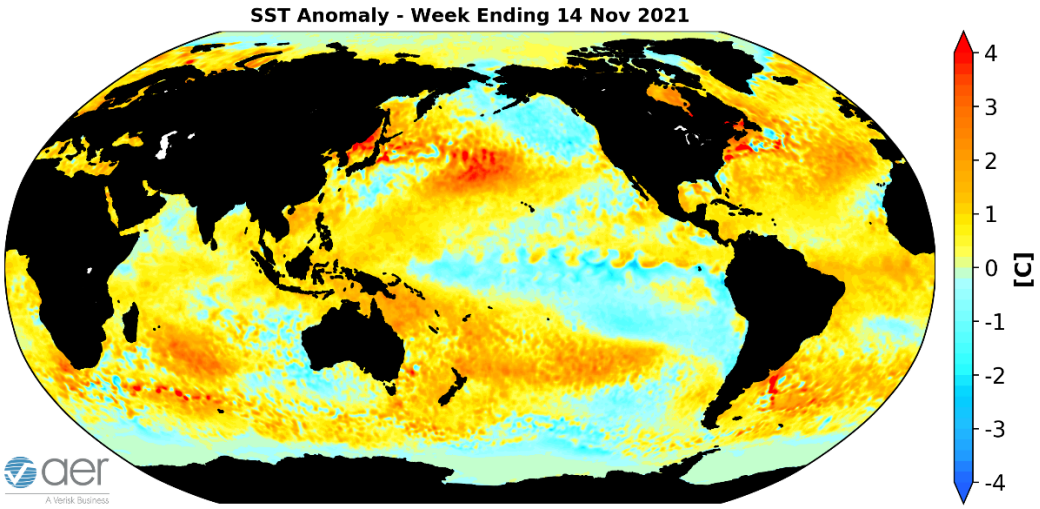

Figure 17. The latest weekly-mean global SST anomalies (ending 14 November 2021). Data from NOAA OI High-Resolution dataset.

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 18**). The forecasts are for the MJO to remain weak where no phase is favored for the next two weeks. Therefore it seems unlikely that the MJO is contributing significantly to the predicted weather pattern across North America over the next two weeks but admittedly this is outside of my expertise.

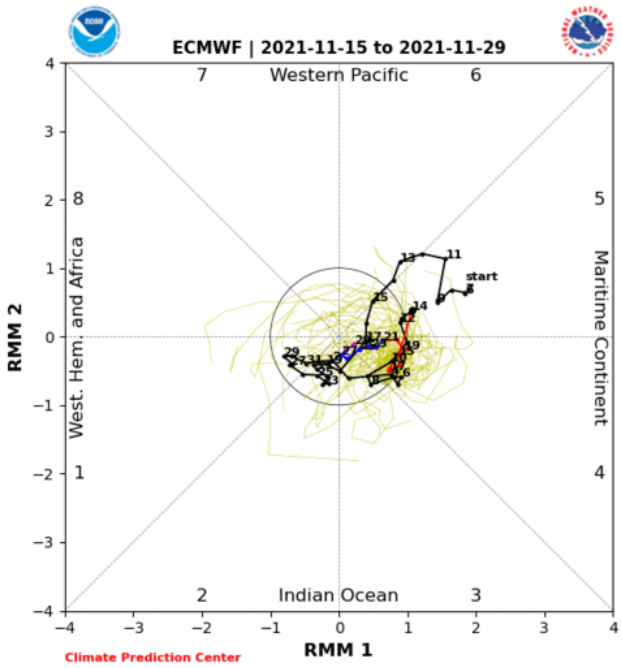

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 15 November 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts,

with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate the phase of the MJO, with geographical labels indicating where anomalous convection occurs during that phase. Image source: http://www.atmos.albany.edu/facstaff/roundy/waves/phasediags.html

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